

# APPENDIX H-1

## Geophysical Report

**PASSIVE SHEAR WAVE VELOCITY SURVEY  
DRY DOCK #1 LIFTING STUDY  
PORTSMOUTH NAVAL SHIPYARD  
KITTERY, MAINE**

*Prepared for:*

Haley & Aldrich, Inc.  
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*Prepared by:*

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File 14J89  
December, 2014

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December 22, 2014  
File 14J89

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RE: Shear Wave Velocity Testing  
Dry Dock #1 Lifting Study  
Portsmouth Naval Shipyard  
Kittery, Maine

Dear Ms. Force:

In this letter, we report the results of geophysical survey conducted by Hager-Richter Geoscience, Inc. (Hager-Richter) at the Portsmouth Naval Shipyard in Kittery, Maine for Haley & Aldrich, Inc. (Haley & Aldrich) of Portland, Maine in December, 2014. The scope of the project and area of interest were specified by Haley & Aldrich.

## INTRODUCTION

The Site is located at Dry Dock #1 at the Portsmouth Naval Shipyard in Kittery, Maine. As part of a study for the Dry Dock #1 Lifting and Handling Improvements, Haley & Aldrich requested a geophysical survey to provide site specific seismic shear wave velocity information as a function of depth for the soil and bedrock. The general Site location is shown in Figure 1.

The shear wave velocity survey was conducted along a single line located south of Building 174 on the landside of Dry Dock #1. The survey line location was selected based on access at the time of the survey. Figure 2 is a plan showing the location of the survey line. The ground surface at the location of the survey line consisted of asphalt pavement. A geologic log from a nearby boring installed by Haley & Aldrich (LB-05), included in the Appendix, indicates that the subsurface in the vicinity of the survey consists of about 5 feet of fill, about 20 to 30 feet of clay, and about 5 to 10 feet of till over bedrock identified as the Kittery Formation. The depth of bedrock in the vicinity varies from about 20 to 40 feet.

## OBJECTIVE

The objective of the survey was to provide seismic shear wave velocity as a function of

depth at Dry Dock #1 at the Portsmouth Naval Shipyard.

## THE SURVEY

Jeffrey Reid, P.G., and Michael Howley, P.G., of Hager-Richter conducted the field operations on December 15, 2014. The project was coordinated with Ms. Erin A. Force, P.E., of Haley & Aldrich. Data analysis and interpretation were completed at the Hager-Richter offices. Original data and field notes will be retained in the Hager-Richter files for a minimum of three years.

The shear wave velocity testing was conducted using the passive shear wave seismic (pVs) method, also called the Refraction Microtremor method, or ReMi™. The pVs method is used to determine a shear-wave velocity profile at the center point of a seismic line by analyzing a particular type of seismic wave recorded on a multichannel record. As indicated above, data for a single pVs survey line were acquired at the site, and its location is shown in Figure 2. The center of the pVs line was located along the south side of Building 174, 115 feet from the southwest corner of Building 174.

## METHODS AND EQUIPMENT

The passive shear wave seismic (pVs) method, also called the Refraction Microtremor method, or ReMi™, is a geophysical method to determine a shear-wave velocity profile at a single location along a line by analyzing a particular type of seismic wave recorded on a multichannel record. The name pVs is derived from p for passive and Vs for velocity of shear waves. The pVs method, also called the Refraction Microtremor method, or ReMi™, uses Rayleigh waves, a particular kind of wave first described by Lord Rayleigh in 1885. Such waves are dispersive (meaning that the velocity is a function of the wavelength), and the amplitude of such waves decreases with depth. The velocity depends primarily on the shear wave velocities and layering of the subsurface material.

Rayleigh waves are a significant part of the ambient subsurface noise at most, if not all, sites. There are many sources of such noise, including, but not limited to, wind, pedestrian and vehicular traffic, surface and subway trains, and construction activities. Although such noise can be troublesome for most seismic methods, it is *the* source of signals for the pVs method, and the higher the noise level, the better the results for this method.

Low frequency (4.5 Hz) geophones are installed 4 to 10 ft apart along a straight line and connected to a seismograph. The ambient noise is recorded for 30 seconds two or three times, and examined to be sure that noise of sufficiently low frequency is present. If the noise is

sufficient, then 10 to 15 such records are acquired. If the noise spectra do not reach sufficiently low frequencies, then one walks or runs along the survey line during data acquisition to add low frequency noise to the ambient noise. The surface waves used in the pVs method, considered noise in refraction and reflection surveys, are *enhanced* during data acquisition and processing for the pVs method. The seismic data are analyzed using SeisOpt® ReMi™, a commercially licensed software package developed by Optim, Inc. located at the University of Nevada at Reno.

The pVs method requires multichannel records with at least 12 traces to produce reliable results. We use a 48-channel digital seismograph (Geometrics Geode), coupled to 48 geophones to acquire better data sets. We use 4.5-Hz low natural frequency geophones for most surveys.

***Site Specific.*** The location for the pVs testing was selected based on site access at the time of the survey, and is shown on Figure 2. The ReMi survey used a geophone spacing of 5 feet and 48 4.5 Hz geophones.

## LIMITATIONS OF THE METHODS

As with all physical measurements, there is experimental error in the velocities that are determined using the pVs method. The accuracy of  $V_{avg}$  is stated by Optim, Inc. to be 5-15%. The depth of investigation is a function of the noise spectrum, and long wave lengths (low frequencies) are required to determine velocity at large depths. Noise levels can be improved by a person running along the seismic spread during data acquisition.

## RESULTS

The pVs survey was conducted along one survey line on the south side of Building 174, with the center of the line located 115 feet from the southwest corner of Building 174. The location of the pVs line is shown in Figure 2. The dispersion curve for the pVs data is shown in Figure 3, and the shear wave velocity profile is reported in Table 1. A geologic log from a nearby test boring (LB-05) installed at the site was provided by Haley & Aldrich, and is included in the Appendix.

Based on the boring log provided by Haley & Aldrich for boring LB-5, which is located about 200 feet from the center of the pVs line, the subsurface at the Site consists of about 5 feet of fill, about 20 to 30 feet of clay, and about 5 to 10 feet of till over bedrock identified as the Kittery Formation. The depth of bedrock in the vicinity varies from about 20 to more than 40 feet below ground surface.

For modeling purposes, the subsurface stratigraphy is broken into discrete units. The velocity units do not necessarily correlate with specific lithologic units. The number of layers and the thickness that provides the best statistical fit to the respective dispersion curve is used. No attempt is made to “force” a specific model to the data.

The data quality for the pVs survey line is excellent, indicated by a sharp contrast in the dispersion curve and low RMS error in fitting the model to the data. The dispersion image, resulting curve, and model are shown in Figure 3, and the interval shear wave velocities,  $V_{s100}$  and RMS error for the pVs survey line are reported in Table 1.

## **LIMITATIONS**

This letter report was prepared for the exclusive use of Haley & Aldrich, Inc. (Client). No other party shall be entitled to rely on this Report or any information, documents, records, data, interpretations, advice or opinions given to Client by Hager-Richter Geoscience, Inc. (H-R) in the performance of its work. The Report relates solely to the specific project for which H-R has been retained and shall not be used or relied upon by Client or any third party for any variation or extension of this project, any other project or any other purpose without the express written permission of H-R. Any unpermitted use by Client or any third party shall be at Client's or such third party's own risk and without any liability to H-R.

H-R has used reasonable care, skill, competence and judgment in the performance of its services for this project consistent with professional standards for those providing similar services at the same time, in the same locale, and under like circumstances. Unless otherwise stated, the work performed by H-R should be understood to be exploratory and interpretational in character and any results, findings or recommendations contained in this Report or resulting from the work proposed may include decisions which are judgmental in nature and not necessarily based solely on pure science or engineering. It should be noted that our conclusions might be modified if subsurface conditions were better delineated with additional subsurface exploration including, but not limited to, test pits, soil borings with collection of soil and water samples, and laboratory testing.

Except as expressly provided in this limitations section, H-R makes no other representation or warranty of any kind whatsoever, oral or written, expressed or implied; and all implied warranties of merchantability and fitness for a particular purpose, are hereby disclaimed.

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Passive Shear Wave Survey  
Dry Dock #1 Lifting Study  
Portsmouth Naval Shipyard  
Kittery, Maine  
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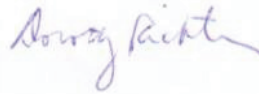
If you have any questions or comments on this letter report, please contact us at your convenience. It has been a pleasure to work with Haley & Aldrich on this project. We look forward to working with you again in the future.

Sincerely,

HAGER-RICHTER GEOSCIENCE, INC.



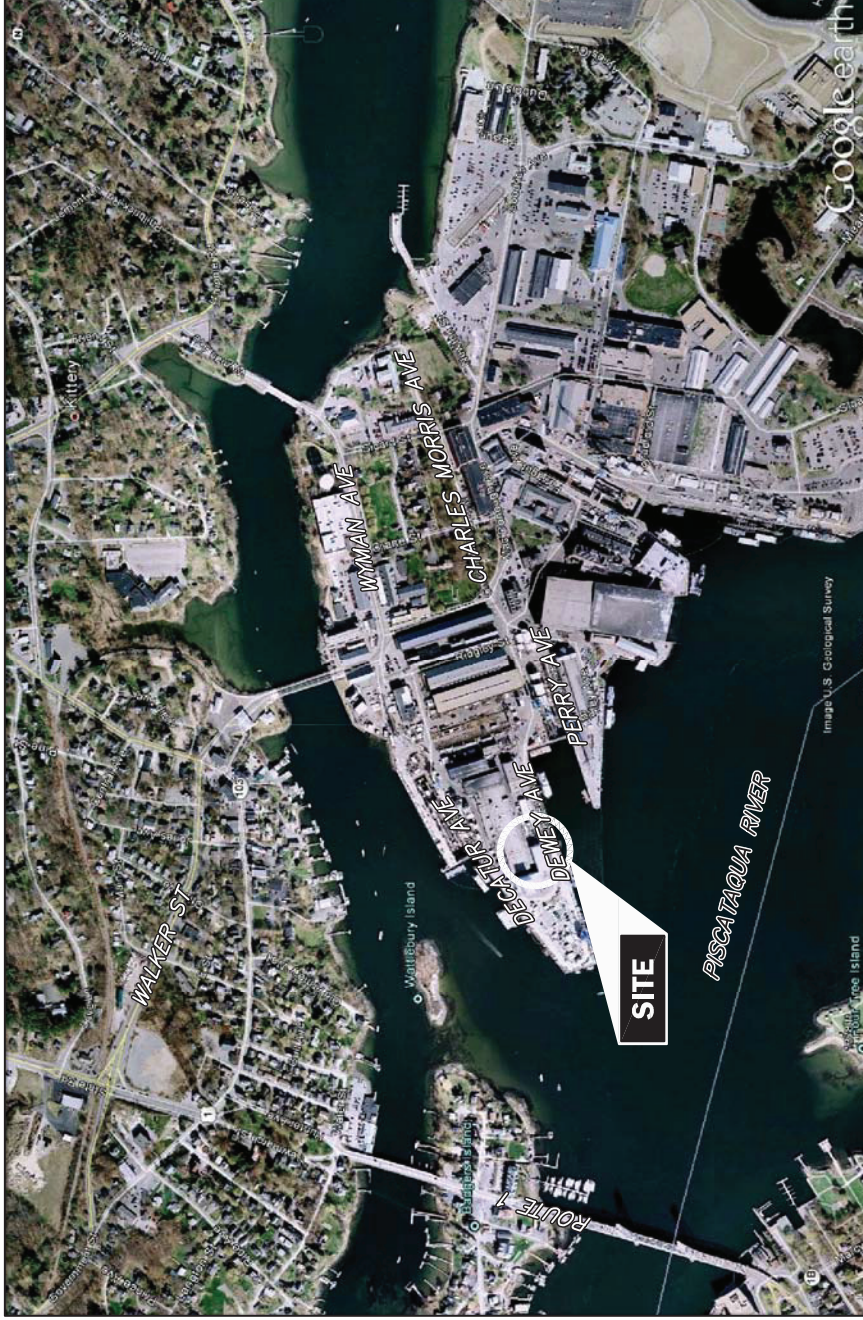
Jeffrey Reid, P.G.  
Vice President/Senior Geophysicist



Dorothy Richter, P.G.  
President

Attachments: Table 1  
                    Figures 1-3  
                    Appendix - Boring Log

<b>Table 1</b> <b>Passive Shear Wave Velocity Survey</b> <b>Dry Dock #1 Lifting Study</b> <b>Portsmouth Naval Shipyard</b> <b>Kittery, Maine</b>	
<b>Depth Interval (ft)</b>	<b>Shear Wave Velocity (ft/sec)</b>
0 - 4	599
4 - 11.5	806
11.5 - 13.5	1107
13.5 - 24	900
24 - 38	2717
38 - 100	4769
<b><math>V_{s100}</math></b>	<b>2137</b>
<b>RMS Error</b>	<b>34 ft/sec</b>



APPROXIMATE SCALE (feet)

0 1000 2000



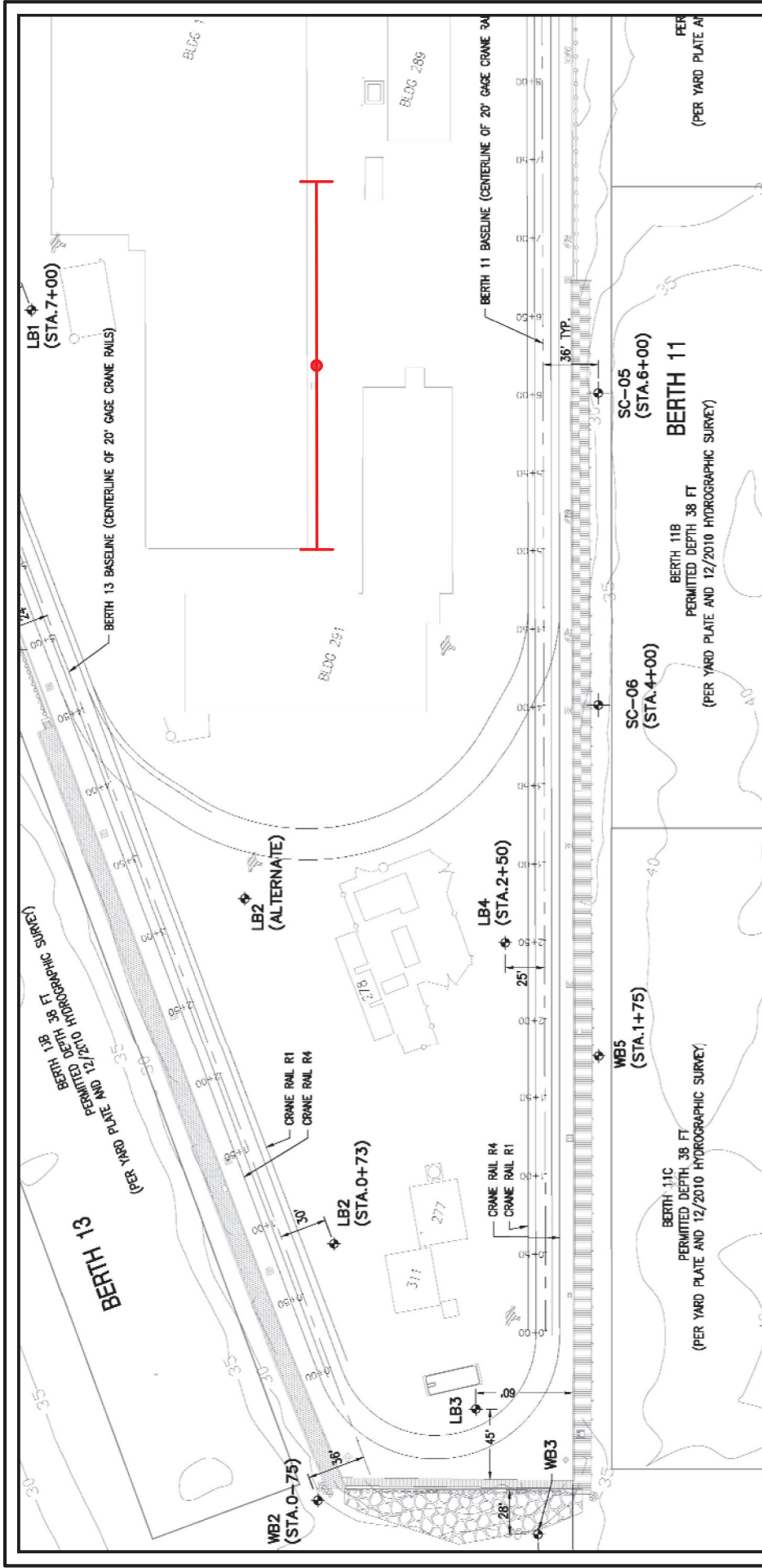
Figure 1  
General Site Location  
Dry Dock #1 Lifting Study  
Portsmouth Naval Shipyard  
Kittery, Maine

NOTE:

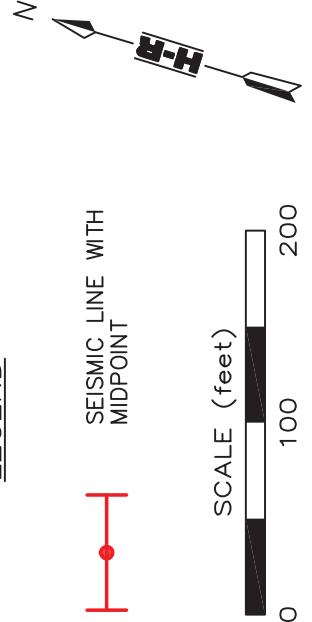
Modified from Google Earth aerial photograph.

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HAGER-RICHTER GEOSCIENCE, INC.  
Salem, New Hampshire



# LEGEND



## NOTE:

Modified from site plan provided by  
Haley & Aldrich, identified as REV  
1 OF 3 BORING PLAN.pdf.

Figure 2  
Site Plan  
Dry Dock #1 Lifting Study  
Portsmouth Naval Shipyard  
Kittery, Maine

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Salem, New Hampshire

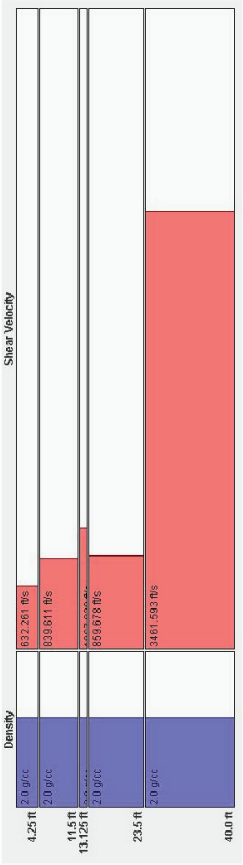
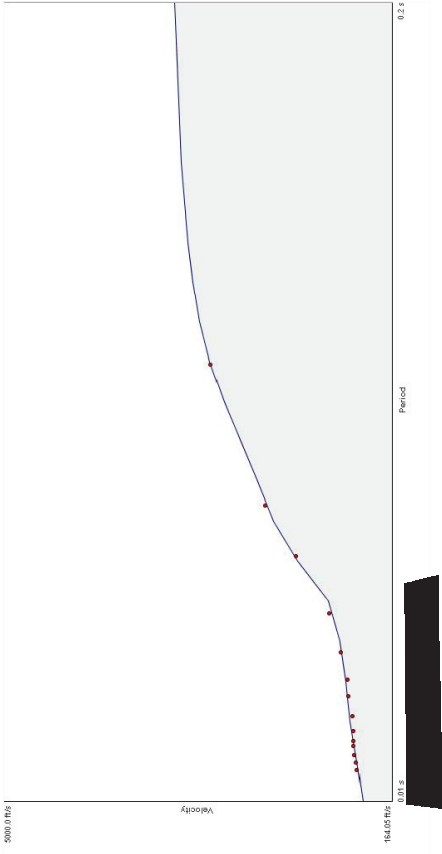
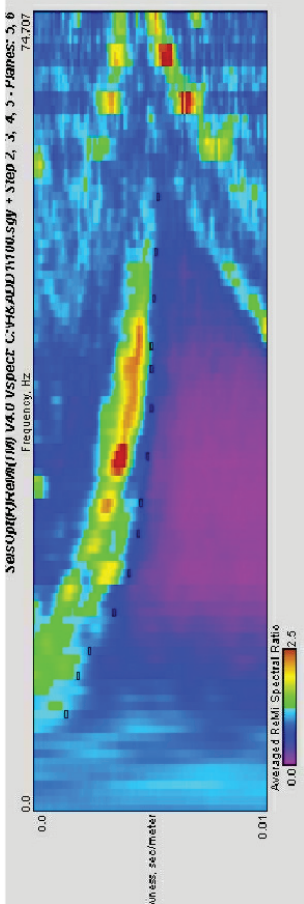


Figure 3  
Dispersion Images & Model  
Dry Dock #1 Lifting Study  
Portsmouth Naval Shipyard  
Kittery, Maine

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